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THE USE OF PORTABLE REFREEZABLE HEAD COOLERS TO REDUCE THERMAL STRAIN DURING MODERATE WORK IN A HOT ENVIRONMENT WHILE WEARING A CHEMICAL DEFENSE GARMENT

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Henning E. von Gierke

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30 mmHg), and air flow at 10-15 m/min. The subjects were dressed with a chemical warfare protective ensemble without the mask. The physical task consisted of pedaling a bicycle ergometer at a load of 60 watts. One test was performed with the use of head cooling, and one test without head cooling. The order of head cooling use was randomized; half of the subjects performed the first test without the cooling system, and half performed the first test with the cooling system. After each test the subjects were placed in the recovery room where ambient conditions were maintained at 29°C Tdb, 24°C Twb (vapor pressure 19.7 mmHg), and air flow at 10-15 m/min. In both tests; heart rate, rectal temperature, and skin temperatures showed an increase during physical work and a decrease during recovery. The use of head cooling limited the magnitude of the increments in all the physiological parameters measured. It was concluded that the use of a portable refreezable head cooler containing ethylene glycol as coolant reduced physiological strain resulting from thermal loads due to heat exposure and metabolic heat production. In addition, the use of head cooling diminished the prevalence and severity of symptomatology resulting from heat stress and improved the subjective feeling of comfort. It was recommended to modify the design of the head cooler in order to increase the cooling efficiency.

PREFACE

This research was performed under the sponsorship of the Harry G. Armstrong Aerospace Medical Research Laboratory, Biodynamics and Bioengineering Division, under project # 7231, from August 1986 to July 1987, with Col. Mary Foley and Lt. Col. William Epperson as Air Force advisors. The utilization of humans for this project was authorized by the Air Force Human Use Committee (AAMRL Protocol 85-20-01), and by the Institutional Review Board Committee at Wright State University (Protocol HSP#556). This report is a dissertation submitted to Wright State University in partial fulfillment of the requirements for the degree of Master of Science in Aerospace Medicine.

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SUMMARY

Heat exposure is a problem in many military operations, particularly in the tropics and in hot areas of the United States. It afflicts people such as military pilots, astronauts, flight line crews, soldiers, steamfitters, firefighters, etc. These people are required to wear protective ensembles for different purposes; for reducing physiological strain due to acceleration; for protection against low barometric pressures; for chemical, biological, and radiation (CBR) protection, etc. There are many other examples of people exposed to heat, such as agricultural pilots, race drivers, industrial workers (canning, textiles, laundering, foundry), miners, athletes, or any other person performing physical activities in hot environments.

Previous research has demonstrated that the human head is an excellent site for removing heat from the body, and cooling of the head is an alternative for protecting people from heat exposure. Preliminary work (unpublished) conducted by Col. Mary Foley at Brooks Air Force Base in San Antonio, Texas, and Wright-Patterson AFB in Dayton, Ohio, resulted in the development of a new moderately priced, portable, refreezable head cooler.

This system was used in our research project to investigate the effectiveness of head cooling for reducing heat strain, during physical work in the heat wearing an impervious suit. 10 male subjects each performed two tests of 1 hr duration, in a climatic chamber where dry bulb temperature (Tdb) was maintained at 38°C, wet bulb temperature (Twb) at 30°C (vapor pressure 30 mmHg), and air flow at 10-15 m/min. The subjects were dressed with a chemical warfare protective ensemble without the protective mask. The physical task consisted of pedaling a bicycle ergometer at a load of 60 watts. One test was performed with the use of head cooling, and one test without head cooling. The order of head cooling use was randomized; half the subjects performed the first test with the cooling system, and half performed the first test without the cooling system. After each test the subjects were placed in the recovery room where ambient conditions were maintained at 29°C Tdb, 24°C Twb (vapor pressure 19.7 mmHg), and air flow at 10-15 m/min. In both tests, heart rate, rectal temperature, and skin temperatures showed an increase during physical work and a decrease during recovery.

The use of head cooling limited the magnitude of the increments in all the physiological parameters measured. It was concluded that the use of a portable refreezable head cooler containing ethylene glycol as coolant reduced physiological strain resulting from thermal loads due to heat exposure and metabolic heat production. In addition, the use of head cooling diminished the prevalence and severity of symptomatology resulting from heat stress and improved the subjective feeling of comfort. It was recommended to modify the design of the head cooler in order to increase the cooling efficiency.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Section 1

INTRODUCTION

As an homeotherm organism, the healthy human being maintains its body temperature within a remarkable narrow range, beyond which the physiological compensatory mechanisms fail. The maintenance of a thermal balance is a fundamental property of temperature control in man.

During exposure to hot temperatures the central warm receptors located in the anterior hypothalamus stimulate the output of sweat glands, produce cutaneous vasodilatation, increase the heart rate and the rate and depth of respiration.

The body gains heat from the environment when the air temperature and the temperatures of surrounding objects exceed body temperature. Under these circumstances the body cannot lose heat through radiation and convection. Therefore, evaporation of sweat represents almost all the body's heat loss at ambient temperatures over 35°C (95°F). However, this mechanism is impaired when ambient relative humidity reaches 75%, and it stops when the relative humidity reaches over 90-95 percent. As the ambient vapor pressure (absolute humidity) increases in hot environments, the capacity for evaporative cooling rapidly decreases (52). This causes a decrease in safe exposure time (5) and of man's working capacity (27).

Working in hot environments places a double stress on the circulatory system, which has to provide oxygen to the working muscles and at the same time increase cutaneous circulation for heat dissipation (47). Physical exercise is an endogenous source of heat which interacting together with hot ambient temperatures and high relative humidity impairs human performance :d heat tolerance. When a person's physiologic capacity to compensate for thermal stress is exceeded, heat can lead to impaired performance and increased risk of accidents, and to clinical signs of heat illness. A rise of body temp. to only 37.3°C (99.1°F) impairs physical performance. A rise to 38.5°C (101.3°F) makes a person uncomfortably hot and aroused. Collapse or heat stroke occurs before the body temperature rises much above 45.5°C (113.9°F) (45).

Ideally, the best way for improving heat tolerance and increase performance is to reach a status of acclimatization, which is characterized by a decrease in heart rate and in rectal and skin temperatures, and by an increase in sweat rate when exposed to a given thermal load (2,14,25,28). Unacclimatized men are more labile for suffering early exhaustion and/or heat stroke than acclimatized men. Acclimatization can be produced naturally or artificially. However, natural or artificial acclimatization cannot provide enough heat tolerance for performing hard physical activities in severe heat. Physical training in a hot environment can provide additional acclimatization to heat, however, some people may be found to be non-adaptable to heat (1).

Although certainly beneficial, adequate reduction of heat strain from extended exposures in excessively hot environments can rarely be accomplished by prior heat acclimatization (16). Therefore, several systems and techniques have been created in order to provide adequate protection against heat exposure and to increase heat tolerance. New designs such as microclimate cooling systems, water cooling systems, air cooling systems, etc., can be used to decrease heat strain by means of extracting heat from the body surface. These systems can cover the whole body or certain body areas only.

Whole body cooling results in maximum reduction of heat strain, and the general pattern for efficiency of cooling suits is from the head down (50). The head is considered the most important region for heat exchange between man and environment. It represents approximately 10% of total body surface and its potential for heat transfer is amplified by: I) Existence of a rich scalp vasculature which remains dilated at low temperatures, II) The possibility of countercurrent heat exchange between the jugular veins and carotid arteries, and, III) The large subjective importance of the head in determining overall thermal comfort (43,44).

Head cooling greatly improves comfort and diminishes facial sweating that frecuently causes blepharospasm ("Sweat blindness") (42). The forehead is particularly sensitive to local skin cooling for reducing facial sweat. Submaximal conductive head cooling can remove 30% of resting body heat (16,43) and about 20% of the metabolic heat production during submaximal exercise (44). In most head cooling experiments, the subjects reported a greater degree of comfort and exhibited increased ability to withstand the heat stress as compared to non-cooling (8,22,30,42,44).

Head cooling can improve heat tolerance and increase performance of personnel exposed to high temperatures by reducing heat strain as well as increasing subjective comfort. Head cooling could also be used as a first aid measure to prevent brain damage due to heat stroke, specially for the very young and the very old who suffer most from heat exposure. Head cooling could be useful in cases of heat exhaustion and to facilitate recovery from heat exposure because it reduces body temperature and sweating, thus, conserving essential body fluids and electrolytes.

Section 2

THERMAL TRANSFER FROM THE HUMAN HEAD

2.1 HEAD SURFACE PHYSIOLOGY IN RESPONSE TO HEAT AND COLD

The surface of the head has certain physiological properties in response to high and low temperature exposures, which explain how head cooling modifies thermal body balance during heat stress. When environmental temperature decreases, heat generation in the head is greater in the periphery than in the center (15). Heat loss from the head represents a large portion of the total heat loss in a cold environment due to its restricted vasomotor response to cold (19). Therefore, thermal insulation of the head must be provided as a protective measure to avoid excessive heat loss during cold exposure. With the body at rest at a core temperature of 22°C (71.6°F) heat production and heat loss from the head are balanced.

The human skin has two types of vasomotor control: In Type 1) Vasodilation is achieved by inhibition of nerves with a vasoconstrictive function, and in Type 2) Vasodilation is achieved by increased activity of nerves with a vasodilative function (17). Vasomotor control of the ear (18,26), cheeks, lips, and nose is mediated by release of the vasoconstrictor tone (17). Vasomotor control of the scalp, forehead (18), chin, submandibular area, neck and upper chest is mediated by active vasodilation (17).

In response to heat exposure there is a release of the vasoconstrictive tone in those areas with Type 1 control, while in areas with Type 2 control there is an active vasodilation. In response to cold exposure there is no skin vasoconstriction in the head (as a whole) which can be considered a natural protective mechanism of the body to help maintain normal brain temperature (19,26). In consequence, there is no consistent change in the circulation index for the head when the ambient temperature is decreased (26). This physiologic condition establishes the basis for the use of head cooling systems.

2.2 ARTIFICIAL HEAD COOLING

Brain tissue (neurones) is particularly vulnerable to body temperatures above the physiologic tolerance point. The continuous removal of heat from the brain by the circulating blood normally prevents overheating (10). Heat tolerance to high core temperature appears to be that of the brain; therefore, cooling of the brain by any means may increase body tolerance to heat. The temperature of the brain is determined by the rate of heat production of the brain tissue, the rate and temperature of the blood flow through the brain, and also by direct heat exchange through the scalp and through the base of the skull (3). There may be selective cerebral cooling due to venous blood returning from facial skin via the ophthalmic vein to the cavernous sinus, where a cooling of arterial blood ascending to the

brain takes place (9,10). Although the head represents only about 7-9% of the total body surface area (13,24), it is the most important region concerning transference of body heat to the environment (20,43,44,50,51,54).

There are several factors that increase the potential of the head for heat transfer to the environment such as:

1) Existence of a highly vascular cutaneous net which remains dilated at low temperatures due to lack of vasoconstrictive innervation (19,26,49,54). Under head cooling conditions, while the rest of the body is exposed to heat, reflex vasodilation occurs which is probably due to blocking of the inhibitory effect of a reduced brain temperature (4).

2) The countercurrent heat exchange ocurring in the neck by which cooling of the scalp might lower the temperature of the carotid artery and circulating blood flowing to the brain (10,36,37,38). The close relationship between veins draining the scalp, face, and neck and the common and internal carotid arteries can explain the mechanism of countercurrent heat exchange (9).

3) The large subjective importance of the head in determining overall thermal comfort (30,43,44,54). Head and body thermal comfort can be maintained during heat exposure by means of head cooling (8). However, under severe heat stress the cooling mechanisms (natural or artificial) are overwhelmed, and the use of a head cooler makes no difference in voluntary tolerance time and comfort (42,44).

Cooling of the head and/or other skin areas reduces heat strain at rest and exercise by lowering heart rates, rectal temperatures and sweat rates (21,30,32,33,34,39,41,51,54). Brouha (7) reported that head cooling reduces the peak heart-rate, total cardiac cost and facilitates recovery from this stress. Head cooling may have a systemic rather than local effect on the body (43,54). Head cooling can remove 30% of the total body heat produced during rest (16,44,54), and 20% of the metabolic heat production during submaximal exercise (44). Cooling of the head reduces local sweating (head and face) probably due to stimulation of skin thermoreceptors (mainly cold receptors) in the head and face, where the concentration of such receptors is high (12,36). Such reduction in facial sweating is very important because sweat in contact with the eyes produces painful blepharospasm (sweat blindness) which can dangerously affect visual performance.

The use of a head cooling system reduces heat strain by means of: A) A change in overall body heat balance, B) A countercurrent effect on temperature of blood supplying the brain, and C) The alterations in sensory output from the scalp, affecting autonomic integration and conscious sensation of comfort. Head cooling can decrease or prevent deterioration of performance (physical and cognitive) during heat exposure (7,32,33). Benor and Shvartz (6), reported that body cooling eliminates the deterioration of performance due to heat stress in a wide range of warm environments but not in extremely hot environments.

The cooling capacity of a given body region depends upon its surface area, local heat production, tissue insulation, vascularity, and maintenance of thermal exchange when chilled by the cooling medium (41,44). A water cooled cap can remove body heat equivalent to about 1/3 of the total metabolic heat production of a seated person (16). Nunneley and Maldonado (42), used a water-cooled cap and/or vest at 15.5°C (60°F) water inlet temperature and reported that head cooling proved 2-3 times as efficient as torso cooling. Shvartz (51), used a water-cooled system with a water inlet temperature of 8.3°C (46.9°F) and reported that cooling the neck is as efficient as cooling the chest. Cooling of the head and neck is even more efficient dissipating heat and reducing heat strain, than cooling an equal area of body surface on the torso, arms, and thighs (49). Kissen et al. (30), used an air-cooled helmet and an air-cooled undergarment at 15.5°C (60°F) air inlet temperature. They reported that cooling of the head and neck is more effective to reduce heat strain than cooling of the torso and legs. Head cooling using a water inlet temperature as low as 5°C , still reduces heat strain without causing head discomfort due to such low temperature (33,34,43,44). Facial cooling reduces rectal temperature, sweat rate and heart rate, increases systemic blood pressure, and increases periphereal vasoconstriction (10,29,35,46). Facial air-cooling is no less effective in reducing heat strain than head cooling using water (31).

Cooling of the head is a useful alternative to whole body cooling in situations where wearing a cooling suit is not operationally acceptable or cooling capacity is limited. Liquid-cooled systems are more effective because they provide 1,000 to 2,000 times greater heat transfer capability than air for the same pumping energy (32). Such difference in heat transfer capability is due to the high specific heat capacity of water compared to the specific heat capacity of air. Effective air-cooling is dependent on active sweating for evaporative cooling, which can be a major limitation for certain environments. Another disadvantage of using air as coolant, is that the effectiveness of such a head cooling system is affected by the insulating effect of the hair. However, despite their lower cooling efficiency and effectiveness, air-cooled systems are preferred for use on board military aircraft because they are lighter, easy to adapt to the existing aircraft systems, probability of failure is lower, and they have been more readily accepted by the user during operational testing (31).

Section 3

EXPERIMENT AND PROCEDURE

3.1 RESEARCH OBJECTIVES

1) To determine the physiological responses of humans working in hot environments while wearing impervious protective clothing with and without the use of head cooling.

2) To establish the effectiveness and efficiency of a portable refreezable head cooler using glycol as coolant for maintaining physical performance of humans working in hot environments while wearing impervious clothing.

3) To determine the operational feasibility of a portable refreezable head cooler to be used during military operations that require the use of chemical warfare protective ensembles, under conditions of environmental heat exposure and increased metabolic heat production due to physical work.

3.2 EXPERIMENTAL DESIGN

The framework of this study was developed around two levels of activity: A) Physical work under ambient heat exposure, and B) Recovery from such exposure in a comfortable environment. For both levels of activity there were two experimental conditions (1) No head cooling, which was designated as Phase I, and (2) Use of head cooling which was designated as Phase II. During both phases, the subjects wore a Chemical Warfare Protective Ensemble.

The sequence for testing each subject under both phases was determined by randomization in order to balance the carry-over effects (fatigue) resulting from being exposed to both conditions. Subjects were tested under both experimental conditions (Phase I and II) the same day, and the experiments were conducted at approximately the same time of the day in order to reduce the effect of circadian rythms.

The environmental chamber was maintained at 38°C (100.4°F) Tdb and at 30°C (86°F) Twb (30 mmHg vapor pressure). The control (recovery) room was maintained at 29°C (84.2°F) Tdb and at 24°C (75.2°F) Twb (19.7 mmHg vapor pressure). The air flow was maintained at about 10 to 15 m/min (30-50 ft/min) in both testing rooms.

When not being worn by the subjects, the head coolers were maintained in a freezer at a temperature of -5°C (23°F). During Phase II, each head cooler was used for a period of 20 minutes and then replaced with another in order to maintain an adequate level of head cooling. A surgical cap was placed between the head cooler and the scalp in order to avoid direct contact with the cold cap, which could cause discomfort due to the low temperature (-5°C) of the coolers.

During both phases, the work duration was 1 hour followed by a 40 minute recovery period. The physical task consisted of pedaling a bicycle ergometer at a low workload of 60 watt for one hour. Subjects were allowed free water intake during both experiments. Water intake and water losses from the body were quantified.

3.3 SUBJECTS

TABLE 1

INDIVIDUAL CHARACTERISTICS OF THE PARTICIPATING SUBJECTS

SUBJECT	AGE (yrs)	HEIGHT (cm)	WEIGHT (kg)	SURFACE AREA (Sq.m)
LP	27	178	69.5	1.8
RJ	37	185	91.8	2.1
CM	27	163	63.0	1.6
WY	27	166	56.5	1.6
JM	29	184	73.0	1.9
BF	35	183	85.7	2.0
JP	36	181	89.2	2.0
SJ	32	176	75.3	1.9
JG	27	185	72.9	1.9
LM	32	175	82.3	2.0
MEAN VALUES	31 yrs	178 cm	75.9 kg	1.9 Sq.m

The subjects were 10 male volunteers, aged 27-37 yrs with a mean age of 31 $\pm$ 4 yrs S.D., a height of 178.0 $\pm$ 8.0 cm, a weight of 75.9 kg $\pm$ 11.3 kg, and a body surface area of 1.9 $\pm$ 0.2 Sq. m.

Ten non heat acclimatized subjects participated in this study. Before the experiment, each participant was required to fill out the consent form and a general information questionnaire [Appendix 1] intended to eliminate those subjects who had any medical conditions that could be considered potential risks for the individual or conditions that could adversely affect the results of the experiment. In addition, at the end of each phase the subjects answered a modified version of the Environmental Symptoms Questionnaire developed by Sampson and Kobrick (48) [Appendix 2]. This questionnaire was used for determining the symptomatology associated with heat stress with and without the use of head cooling.

3.4 MATERIALS AND INSTRUMENTATION

As a cooling system we used commercially available refreezable head coolers (Col-Pak hydrocollator) manufactured by Chattanooga Corporation (55). Each head cooler consists of three large, flat, vinyl cells (2 lateral and 1 central) sticked together along their edges, and 1 (forehead) removable cell. Each head cooler contains 1.6 kg of a very thick mixture of bentonite clay and glycol as coolant [Fig. 1]. Disposable surgical caps were placed between the scalp and the head cooler for protection against frostbite. All the subjects wore chemical warfare protective suits (charcoal-impregnated), hood (no mask), rubber gloves, and rubber boots. A Monark bicycle ergometer was used for performing the physical task.

An Arvin heavy duty utility convective heater model 29H90-1 and a DeLonghi air heater model 5108 were utilized for maintaining the proper temperature in the chamber. A 6 inch. electric desk fan model HF-15SPP was used for maintaining a constant air flow in the chamber.

The following instrumentation was used for physiological and environmental measurements: A YSI Tele-Thermometer model 46, a YSI Tele-Thermometer model 43, and a YSI Tele-Thermometer model 42 SC. In conjunction with the thermometers we used various probes: A YSI Air temperature probe model 405, YSI Rectal temperature probes model 401, YSI Attachable surface temperature probes model 409A, and a YSI Oral temperature probe model 408. For measuring subject's weight we used a Heathkit precision weight scale with a 0.1 Kg accuracy. A Hanson dietetic scale model 160-1 was used for calculation of ingested water. Finally, a portable sling psychrometer was utilized for determination of ambient humidity.

FIG. 1 Photograph of the head cooler

3.5 PHYSIOLOGICAL MEASUREMENTS

Control (initial) measurements of heart rate, oral temperature, rectal temperature and skin temperatures were recorded in the air conditioned dressing room before starting each phase.

During both experimental conditions, heart rate and rectal temperature were continuously monitored. A heart rate of 180 beats per minute and/or a rectal temperature of 39°C (102.2°F) were used as termination criteria.

Heart rate, rectal temperature, oral temperature and skin temperatures were recorded every 30 minutes during the work period and during the recovery period in both phases.

3.6 EXPERIMENTAL PROCEDURE

Each subject was tested under both experimental conditions (Phase I and II). The subjects were requested not to eat at least one hour before starting the experiments, and to remain at rest during the 10 minutes preceding the test. Subjects were weighed nude before and after each phase to determine sweat loss. While the subjects were at rest, skin probes were taped on the following body areas: Forehead, upper arm, lower arm, chest, back, upper leg, and lower leg. Three EKG electrodes were placed, one on the right infraclavicular area, another on the left infraclavicular area, an the last one below the xyphoid process. In addition, subjects inserted a rectal probe 10 cm. into the rectum for measurement of rectal temperature. After being instrumented, subjects dressed with a chemical warfare protective assembly which included a hood (no mask), an impermeable suit (charcoal-impregnated), cotton gloves, rubber gloves, and rubber boots [Fig. 2]

Control measurements of all the physiological parameters were taken in the dressing (recovery) room. Then the subjects were placed in the environmental chamber at the required environmental conditions and initiated the physical task pedaling a bicycle ergometer at 60 rpm for 60 min at a low load (60 watt).

Upon termination of the work period, the subjects were placed in the recovery room and remained seated for 40 minutes. Physiologic data were recorded every 20 minutes. During recovery, subjects were permitted to remove only the gloves and the hood. After finishing recovery, subjects removed wet clothing and replaced it with dry clothing and remained at rest for 10 more minutes.

The subjects continued with the second part of the experiment (either Phase I or II) and the same experimental procedure was repeated. During phase II each head cooler was removed after 20 minutes of use and replaced with another. Surface temperature was measured using a YSI temperature probe model 408, at six different points (2 anterior, 2 medial, 2 posterior) on the inner surface of head cooler after removal from the subject's head. Mean temperature of each head cooler was obtained from the average of the six points measured, before and

after use.

Mean skin temperature was calculated using the method developed by Ramanathan (45A). Mean upper body temperature was calculated using data from chest, back and upper arm temperatures, while mean lower body temperature was calculated using data from lower arm, upper leg and thigh temperatures. Core temperature (rectal) was considered and denominated Body Temperature in the discussion of results.

FIG. 2 Photograph of a subject dressed for the experiment

Section 4

RESULTS

The results from this experiment are summarized in the following tables, and all the data from both experimental conditions were compared using a standard two-tailed Paired t-test.

TABLE 2

MEAN VALUES FOR ALL PHYSIOLOGICAL VARIABLES AT 30 MINUTES OF WORKING IN A HOT ENVIRONMENT

VARIABLE	CONDITION HEAD COOLING		MEAN DIFF.	S.E.	SIGNIFICANCE
	WITHOUT	WITH			
Heart Rate (BPM)	111	106	5	1.9	*
Rectal T (°C)	37.6	37.5	.1	.06	NS
Oral T (°C)	37.1	36.9	.2	.1	NS
Forehead T (°C)	37.1	24.8	12.3	.9	**
Mean Skin T (°C)	36.8	36.6	.2	.1	NS
Upper Body T (°C)	36.9	36.6	.3	.09	**
Lower Body T (°C)	36.6	36.5	.1	.2	NS

S.E.= Standard error
* $p<0.05$
** $p<0.01$
NS not statistically significant

Table 2 summarizes physiological data obtained after 30 minutes of working in the heat. This table shows that with the use of head cooling the difference in heart rate was statistically significant. However, from a physiological point of view this difference (5 BPM) was not meaningful. Rectal temperature showed no significant difference because of the the delayed response of this anatomical area in responding to heating and/or cooling. The difference in oral temperature was not significant. Forehead temperature, decreased as expected due to the local effect of cooling. Mean skin temperature and mean lower body temperature did not show a significant change. Mean upper body temperature was significantly lower when using head cooler, which may suggest a regional effect of head cooling. But again, not meaningful in a physiological sense.

TABLE 3

MEAN VALUES FOR ALL PHYSIOLOGICAL VARIABLES AT 60 MINUTES
OF WORKING IN A HOT ENVIRONMENT

VARIABLE	CONDITION HEAD COOLING		MEAN DIFF.	S.E.	SIGNIFICANCE
	WITHOUT	WITH			
Heart Rate (BPM)	124	114	10	2.3	**
Rectal T (°C)	38.1	37.8	.3	.09	**
Oral T (°C)	37.6	37.2	.4	.09	**
Forehead T (°C)	37.2	26.8	10.4	.6	**
Mean Skin T (°C)	37.2	36.8	.4	.1	*
Upper Body T (°C)	37.4	36.9	.5	.1	**
Lower Body T (°C)	37.0	36.8	.2	.1	NS

S.E.= Standard error
* $p<0.05$
** $p<0.01$
NS not statistically significant

Table 3 summarizes the physiological data obtained after 60 minutes of working in the heat and shows that the use of head cooling reduced heart workload. Rectal temperature showed a significant reduction which may be attributed to cooling of circulating blood. The only significant difference in oral temperature during the whole experiment was observed during this period, and it may be due to the local effects of cooling and/or to the cooling effect of the ingested water. All physiological parameters except lower body temperature significantly declined with the use of head cooling. Mean lower body temperature did not decr ase probably due to local heat production of the working muscles in the legs.

TABLE 4

MEAN VALUES FOR ALL PHYSIOLOGICAL VARIABLES AT 20 MINUTES DURING RECOVERY

VARIABLE	CONDITION HEAD COOLING		MEAN DIFF.	S.E.	SIGNIFICANCE
	WITHOUT	WITH			
Heart Rate (BPM)	94	82	12	2.3	**
Rectal T (°C)	38.0	37.6	.4	.09	**
Oral T (°C)	37.1	36.9	.2	.1	NS
Forehead T (°C)	35.2	21.7	13.5	1.4	**
Mean Skin T (°C)	36.0	35.2	.8	.1	**
Upper Body T (°C)	36.1	35.2	.9	.2	**
Lower Body T (°C)	36.0	35.3	.7	.1	**

S.E.= Standard error
* p<0.05
** p<0.01
NS not statistically significant

Table 4 summarizes physiological data obtained after 20 minutes of recovery, and shows that with the use of head cooling all the parameters except oral temperature improved and showed highly significant differences ($p < 0.01$).

TABLE 5

MEAN VALUES FOR ALL PHYSIOLOGICAL VARIABLES AT 40 MINUTES DURING RECOVERY

VARIABLE	CONDITION HEAD COOLING		MEAN DIFF.	S.E.	SIGNIFICANCE
	WITHOUT	WITH			
Heart Rate (BPM)	86	77	9	3.2	**
Rectal T (°C)	37.8	37.4	.4	.1	**
Oral T (°C)	36.9	36.8	.1	.1	NS
Forehead T (°C)	34.5	21.9	12.6	.9	**
Mean Skin T (°C)	35.3	34.8	.5	.2	*
Upper Body T (°C)	35.3	34.7	.6	.2	*
Lower Body T (°C)	35.3	34.8	.5	.2	*

S.E.= Standard error
* $p<0.05$
** $p<0.01$
NS not statistically significant

After 40 minutes of recovery Table 5, all the physiological parameters except oral temperature showed a significant difference with the use of head cooling. However, the mean differences were smaller than those reported after 20 minutes of recovery.

TABLE 6

COMPARISON OF PHYSIOLOGIC VARIABLES BETWEEN CONTROL AND POST COOLING

VARIABLE	CONTROL	POST COOLING	MEAN DIFF.	S.E.	S. LEVEL
Heart Rate (BPM)	78	77	1.5	3.1	NS
Rectal T (°C)	37.5	37.4	.1	.1	NS
Oral T (°C)	36.7	36.8	.1	.2	NS
Forehead T (°C)	34.1	21.9	12.1	.9	**
Upper Body T (°C)	34.4	34.7	.5	.2	NS
Lower Body T (°C)	34.0	34.8	1.0	.2	**
Mean Skin T (°C)	34.2	34.8	.5	.2	NS

S.E.= Standard error
** $p<0.01$
NS not statistically significant

Table 6 shows the results of comparing the values of the different physiological parameters recorded at the beginning of the experiment (control) and after finishing the recovery period during Phase II (Head Cooling). In other words, we compared the control measurements with the final measurements at the end of Phase II in which the head coolers were used during work and recovery. The purpose of such comparison was to establish if the use of head cooling decreases recovery time to the pre-exposure physiological conditions. Except for forehead and lower body temperatures, all the other physiological parameters returned to pre-exposure (control) values after 40 minutes of recovery using the cooling system.

TABLE 7

MEAN TEMPERATURES ON THE INNER SURFACE OF THE HEAD COOLERS AFTER 20 MINUTES OF USE

HEAD COOLER GROUP *	FINAL TEMPERATURES
1 (after 1st 20 min of work)	16.7 °C
2 (after 2nd 20 min of work)	18.4 °C
3 (after 3rd 20 min of work)	21.1 °C
4 (after 1st 20 min of recovery)	15.8 °C
5 (after 2nd 20 min of recovery)	14.3 °C
OVERALL MEAN TEMP	17.3 °C

* Each group includes the mean values obtained by measuring the surface temperature of the inner surface of 10 head coolers after 20 minutes of use.

The mean temperature of each head cooler was obtained after 20 minutes of use when it was replaced for another. Five consecutive head coolers were used by each subject during Phase II; three during the work period, and two during the recovery period. The initial temperature of all the head coolers was -5°C, and the overall mean temperature of the five groups of head coolers after use was 17.3°C. The temperature of the inner surface of the head coolers increased 22.3°C (-5°C to 17.3°C) after being worn by the subjects. Each head cooler weighs 1.6 kg and contains a mixture of 640 g of bentonite clay (40%) and 960 g of ethylene glycol (60%), which have an specific heat of 0.22 kcal/kg, and .571 kcal/kg respectively. The cooling power of the head coolers was 15.4 kcal/20 min.

TABLE 8

VOLUNTARY INGESTION OF WATER DURING HEAT STRESS

SUBJECT	PHASE I NO COOLING (g)	PHASE II COOLING (g)
LP	1,500	1,050
RJ	1,200	600
CM	600	200
WY	600	300
JM	1,200	1,050
BF	600	400
JP	900	200
SJ	550	650
JG	1,000	800
LM	600	400
MEAN VALUES	875 grams	565 grams

Table 8 shows data about voluntary ingestion of water at room temperature during heat stress with and without head cooling. The mean difference in water ingestion between both phases was 310 g with a standard error of 74.1 g. The difference was significant at the P level of <.01 suggesting that with the use of head cooling the body may lose less fluids. Therefore, decreasing the need for water; however, more data is required to prove such a hypothesis.

Mean Weight Loss during Phase I (without cooling) was 1,190 g while during Phase II (cooling) weight loss was 900 g, the mean difference in weight loss between Phase I and II was 290 g with a standard error of 256 g. This difference was not significant and we were not able to demonstrate a significant difference in the amount of sweat loss measured by weight loss with the use of head cooling. The amount of water ingested by the subjects was substracted from the measurements of body weight.

TABLE 9

PHYSIOLOGICAL HEAT STRAIN INDEX AND BODY HEAT STORAGE

CONDITION	NO COOLING	COOLING
Heat-Strain Index	3.13	2.34
Body-Heat Storage (Cal/Sq.m/Hr)	22.8	9.8

Table 9 shows that the use of a refreezable head cooler reduced heat strain using the heat strain index. It a also helped to reduce body heat storage.

We used the modified Craig index of physiological strain (23):

$$Is = (HR/100) + Tr + Wn$$

where HR = terminal heart rate
Tr = rise in rectal temperature (°C/hr)
Wn = sweat production (nude wt. loss, Kg/hr)

For calculating body heat storage we used the following formula (23):

$$q = (WCp/Ab) \times (Tb)$$

where W = nude body weight (kg)
Cp = specific heat of body mass (0.83; Cal/g/°C)
Tb = change in mean body temperature (°C)
Ab = surface area of body (Sq.m)

TABLE 10

SUMMARY OF RESULTS FROM THE ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE

SYMPTOM	# OF SUBJECTS REPORTING THE SYMPTOM						
	NO COOLING	SEVERITY		COOLING	SEVERITY		
		0-2	3-5		0-2	3-5	
Headache	4	3	1	2	1	1	(+)
Head Throbbing	6	4	2	3	2	1	(*)
Light Headed	4	2	2	4	2	2	(=)
Feel Faint	2	0	2	2	2	0	(=)
Hard to Breathe	3	2	1	2	1	1	(+)
Breathe Fast	4	2	2	4	3	1	(=)
Breathe Irregular	4	3	1	3	2	1	(+)
Nausea	3	3	0	2	1	1	(+)
Heart Rate Fast	8	4	4	6	5	1	(+)
Heart Pounds	5	3	2	5	5	0	(=)
Tense Muscles	4	4	0	3	3	0	(+)
Muscles Ache	4	4	0	3	3	0	(+)
Feel Weak	5	3	2	5	4	1	(=)
Feel Warm	10	3	7	8	6	2	(+)
Feel Feverish	6	5	1	1	1	0	(*)
Hands Sweaty	10	4	6	8	4	4	(+)
Sweating	9	0	9	10	4	6	(+)
Skin Sensitive	4	4	0	1	1	0	(*)
Eyes Irritated	5	4	1	1	1	0	(*)
Watery Eyes	5	4	1	1	1	0	(*)
Blurry Vision	3	2	1	2	2	0	(+)
Dry Mouth	8	7	1	5	4	1	(*)
Sense of balance Off	5	5	0	4	4	0	(+)
Feel Clumsy	4	4	0	4	4	0	(=)
Feel Tired	8	6	2	7	5	2	(+)
Feel Sleepy	6	4	2	6	3	3	(=)
Trouble Concentrating	4	2	2	3	2	1	(+)
Feel Bored	5	2	3	7	5	2	(+)
Feel Irritable	4	3	1	4	3	1	(=)

(=) Same number of subjects with the symptom in both groups.
(+) 1 or 2 subjects without the symptom with head cooling.
(*) 3 or more subjects without the symptom with head cooling.

Table 10 summarizes the results from the environmental symptoms questionnaire. Each symptom was investigated based on a numerical scale from 0 to 5 depending on the perceived severity of such symptom [Appendix 2]. In general, our results show that with the use of head cooling the subjects reported less symptomatology associated to heat stress. In addition, the symptomatology reported while the subjects were wearing the coolers was less severe than the symptomatology

reported during heat exposure without head cooling. Such observation (severity) also applies to those symptoms which were reported by the same number of subjects in both groups.

Symptoms such as head throbbing, light headedness, concentration problems, feeling feverish, sensitive skin, feeling bored and/or feeling irritable, may be factors that could affect cognitive performance under conditions of heat stress. More data is necessary to support this hypothesis.

The use of head cooling seems to decrease the presentation and severity of symptoms such as eye irritation, watery eyes and blurry vision, which may be attributed to an avoidance or reduction of sweat going into the eyes. This situation may be attributed to a reduction in sweat secretion from the head and forehead, but this assumption deserves further investigation.

Section 5

DISCUSSION

Under the conditions of this experiment, it was observed that the use of head cooling during the first 30 minutes of work in the heat may have a regional effect, as shown by a statistically significant reduction in the mean upper body temperature. In addition, the observed heart rate was significantly lower suggesting a systemic effect of head cooling. However, this change was not physiologically important and the overall physiological response did not change.

After 60 minutes of work in the heat, all the physiological parameters increased; however, with the use of head cooling increases were smaller and heat strain was reduced. These results are in accordance with previous reports indicating that head cooling does not prevent rise in deep body temperature, but it limits the magnitude of the increase in the temperature (8).

Data collected after 20 minutes of recovery from heat exposure and physical work, suggest that the use of head cooling reduced heat strain more effectively during recovery because metabolic generation of heat and heat gain from the environment decrease or are eliminated.

Even though head cooling was maintained during the entire recovery period, our results show smaller changes in the physiological parameters during the last 20 minutes than during the first 20 minutes of recovery. This observation may be explained by taking into account that after 40 minutes of recovery, the physiological functions of the body are closer to the levels of normality than after only 20 minutes of recovery. Therefore, even if the the cooling power is maintained at the same level, the mean differences required to reach physiological normality are smaller during the last 20 minutes of recovery.

The results suggest that the use of head cooling during work in heat and during recovery from exposure, facilitates and accelerates the return to the pre-exposure physiological conditions (Table 6). Mean lower body temperature did not return to pre-exposure values. A possible explanation is that even with the subjects at rest, the ambient temperature was slightly above the neutral zone and they were still dressed with the impermeable suit that prevents evaporative cooling. Under such conditions, slightly high skin temperatures were maintained especially on those areas (legs) located far from the cooling source and where the impervious suit was tighter.

It was observed that the temperature of the head coolers increased with increased time of exposure of the subjects and with increased body heat production due to physical work (Table 7). During recovery the head coolers showed lower final temperatures due to a decrease in heat transfer from the head to the inner surface of the cooler. Such decrease in heat transfer may be due to a decreased metabolic heat production as well as to the termination of heat exposure.

It has been reported in the literature that head cooling has a local effect only, because average skin temperature, sweat rate, and oral and tympanic temperatures show minimum changes (32,49). However, our results suggest that head cooling may also have an internal systemic effect (by local cooling of the blood) as shown by a significant decrease in rectal temperature and heart rate. An external regional effect may also be present as indicated by a significant change in mean upper body temperature. Even though mean skin temperature is a useful generalization, it should not be allowed to obscure the regional temperature differences during head cooling, such as those observed in our experiment.

The use of head cooling reduces head temperature and the inclusion of head temperature in the calculation of mean skin temperature produces a drop in the final value (40,54). Therefore, for the calculation of mean skin temperature and mean upper body temperature in this experiment head temperature was excluded.

It has been reported that with decreased skin and core temperatures, there is lower body heat content and less strain on the heat transfer mechanisms, that allows more blood to be available for the working muscles (22). Heat strain reduction refers to the degree of reduction in heart rate, rectal temperatures, sweat rate or body heat storage (50). Many authors have reported heat strain reduction with the use of head cooling (30,32,33,41,44). Using the method of Hall and Polte (23), heat strain index and body heat storage were calculated on our subjects with and without the use of head cooling. The results indicate that heat strain index and body heat storage were decreased with the use of head cooling (Table 9). These indices have been used by Webbon et al. (53), and by Williams and Shitzer (54).

Previous reports in the literature showed that head cooling improves the subjective feeling of comfort during heat exposure (8,11,30,42,43,44). The results of this experiment support the hypothesis that the use of head cooling during heat stress maintains thermal comfort and/or reduces discomfort (subjectively), even in the absence of significant improvement in the overall physiological status.

Coolant temperatures of 0°C (32°F) can produce frostbite (41). In this experiment temperatures of -5°C did not cause any injury to the forehead or to the scalp. However, two subjects reported headache ("Ice Cream Headache") while wearing the head cooler during the recovery period, which was attributed to the low temperature of the cooler. One subject had projectile vomiting, and reported dizziness and weakness when his forehead temperature reached 12°C (53.6°F).

Several operational problems with the use of a refreezable head cooler during physical work in the heat were found. Each head cooler consists of 3 large cells (2 lateral and 1 central), and a separate cell for the forehead (Fig. 2). Certain areas of the cooler do not maintain good contact with the surface of the head, such as union areas between the three cells, and the occipital region of the cooler which does not follow the contours of the head and posterior neck. In

addition, the central compartment by itself is not capable of maintaining the coolant equally distributed along the covered areas of the head, mainly the top (vertex). This problem is slightly worse when the viscosity of the coolant decreases during heat dissipation from the head and gravity pulls the coolant to the lowest part of the cell. Therefore, it is necessary to squeeze that part of the cell to force the coolant up to the head. It was found that the coolant in contact with the inner surface of the cooler was at higher temperature than the coolant in contact with the external surface when worn by the subjects. In order to maintain an adequate thermal gradient between the head and the cooler that facilitates heat dissipation, it is necessary to replace the relatively warm coolant with cold coolant. This can be accomplished by means of squeezing and/or pressing down the cells of the cooler. Another operational problem is the necessity of keeping the head coolers in a freezer which requires an energy source.

There were some problems with the use of a chemical protection mask, which covers the forehead and is affixed against the face by elastic straps around the head. Under such conditions, there is only a moderately adequate contact between the head cooler and the scalp (including the forehead) which reduces the effectiveness and efficiency of the cooler. Therefore, it was decided to exclude the use of a mask in the experiment.

Section 6

CONCLUSIONS

1.- The use of a portable refreezable head cooler reduced physiological strain resulting from thermal loads due to environmental heat exposure and metabolic heat production.

2.- The study demonstrated the effectiveness of using a head cooler containing glycol as coolant for maintaining physical performance at lower levels of strain during heat stress as indicated by the heat strain index.

3.- The results suggest that the use of head cooling during recovery from heat exposure may facilitate and accelerate the recuperation of the body to the initial (pre-exposure) physiological conditions. The use of head cooling during recovery deserves further investigation.

4.- The use of head cooling decreases the prevalence and severity of symptomatology resulting from heat stress, and improves the subjective feeling of comfort.

5.- This head cooler can be used by people wearing impervious protective clothing performing moderate work in the heat. However, certain changes in the design of the head cooler must be done. Such modifications are described later.

6.- It was not possible to establish the operational feasibility of the head cooler for being used during military operations requiring NBC clothing, because the subjects did not use the protective mask.

Section 7

RECOMMENDATIONS

HEAD COOLER

1.- The head cooler should be re-designed taking into account anthropometric measures of the head in order to improve surface contact area.

2.- Instead of 3 large compartments the head cooler should be divided into 7 separate compartments to maintain the coolant equally distributed on the head.

3.- If it is possible, a different coolant (lighter) should be evaluated under similar experimental conditions, in an attempt to reduce the total weight of the head cooler while keeping the cooling capacity.

4.- It is also necessary to improve the restraint system in order to keep the head cooler in the correct position, even if the individual is moving his head during work.

5.- In order to establish the cooling efficiency of this refreezable system, future research should be oriented to determine the rate of loss of cooling capacity of the head cooler as a function of body temperature, environmental temperature, and time of exposure.

EXPERIMENTAL DESIGN

1.- The size of the sample should be increased because physiological variables only showed small changes under the different experimental conditions. Therefore, when such kind of variables are utilized sample size may affect the significance of the results due to individual variability.

2.- It was unfortunate that in this experiment it was not possible to record all the variables at shorter time intervals, as it has been suggested in the literature. In the future, the experimental design should provide the means to record all the physiologic variables at least every 5 minutes.

3.- It is suggested the use of an electrocardiograph for continuous monitoring and recording of heart rate instead of a cardiotachometer which may be less accurate.

4.- The water provided to the subjects during the experiment should be maintained at neutral temperature (not cold or warm) especially if oral temperature is one of the physiologic variables recorded.

USE OF A PORTABLE REFREEZABLE HEAD COOLER TO INCREASE HEAT TOLERANCE OF PERSONNEL WORKING IN HOT ENVIRONMENTS AND TO FACILITATE RECOVERY FROM HEAT EXPOSURE

QUESTIONNAIRE FOR PARTICIPANTS

1.- LAST 4 DIGITS OF YOUR SSN:________________.

2.- DATE:____________________________________.

3.- AGE:_____________________________________.

4.- SEX:_____________________________________.

5.- ASIAN ( ) BLACK ( ) HISPANIC ( ) WHITE ( ) OTHER ( )

6.- HEIGHT:__________________________________.

7.- WEIGHT:__________________________________.

8.- OCCUPATION:______________________________.

9.- LENGTH OF TIME IN PRESENT OCCUPATION AND INDICATE WHERE (LOCATION) HAVE YOU BEEN WORKING DURING THE LAST 2 MONTHS:______________________________.

10.- INDICATE EXTRA CURRICULAR PHYSICAL ACTIVITIES INCLUDING SPORTS SPECIFYING FRECUENCY (WEEKLY/DAILY) ____.

11.- SMOKER/NONSMOKER (IF SO HOW MANY PACKS A DAY)____________________________.

12.- HOW MUCH BEER, WINE OR HARD LIQUOR DO YOU DRINK DAILY ?__________________.

13.- STATUS OF PHYSICAL FITNESS (GOOD, AVERAGE, BELOW AVERAGE)_______________.

14.- CURRENTLY USE OF ANY MEDICATION:
NO ( )
YES ( ) -- TYPE AND PURPOSE:____.

15.- MEDICAL HISTORY -- HAVE YOU HAD DURING THE LAST WEEK OR HAVE NOW ANY OF THE FOLLOWING ??

CONDITION	YES	NO
FREQUENT OR SEVERE HEADACHES................	( )	( )
DIZZINES OF FAINTING SPELLS.................	( )	( )
UNCONSCIOUSNESS FOR ANY REASON..............	( )	( )
HAY FEVER...................................	( )	( )
ASTHMA ATTACK...............................	( )	( )
HEART TROUBLE...............................	( )	( )
HIGH OR LOW BLOOD PRESSURE..................	( )	( )
STOMACH TROUBLE INCLUDING DIARRHEA..........	( )	( )
KIDNEY STONE OR BLOOD IN URINE..............	( )	( )
SUGAR OR ALBUMIN IN URINE...................	( )	( )
EPILEPSY OR FITS............................	( )	( )
NERVOUS TROUBLE OF ANY SORT.................	( )	( )
ANY DRUG OR NARCOTIC HABIT..................	( )	( )
DEPRESSION OR ANXIETY.......................	( )	( )
OTHER ILLNESSES.............................	( )	( )

FOR EACH "YES" CHECKED DESCRIBE CONDITION:____________________________

____

____

______________________________.

THANK YOU FOR YOUR PARTICIPATION.

USE OF A PORTABLE REFREEZABLE HEAD COOLER TO INCREASE HEAT TOLERANCE OF PERSONNEL WORKING IN HOT ENVIRONMENTS AND TO FACILITATE RECOVERY FROM HEAT EXPOSURE

" ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE "

(Phase One: Post Heat-Exposure without Head Cooler)

A) LAST 4 DIGITS OF YOUR SSN:______________.

B) DATE_________________________________.

C) SELECT YOUR TEMPERATURE SENSATION:
( ) COMFORTABLE.
( ) SLIGHTLY WARM.
( ) WARM.
( ) HOT.
( ) VERY HOT.
( ) PAINFULLY HOT.

D) DEFINE YOUR WORK LOAD IN ACCORD WITH THE FOLLOWING WORK INDEX:
( ) EASY WORK.
( ) LIGHT WORK.
( ) MODERATE WORK.
( ) HEAVY WORK.
( ) EXHAUSTING WORK.

E) DO YOU THINK YOU COULD HAVE CONTINUED AND DONE MORE WORK ?
( ) YES.
( ) NO.

INSTRUCTIONS : Indicate whether you have any of the symptoms below RIGHT AT THIS MOMENT by circling the appopiate number for each item. Answer all items. (Note: It is possible for you to have none of the symptoms below. However, since it is important that you read every statement, respond to each statement individually.)

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUIT A BIT	EXTREME
1.- I HAVE A HEADACHE........................	0	1	2	3	4	5
2.- MY HEAD IS THROBBING.....................	0	1	2	3	4	5
3.- I FEEL LIGHT HEADED......................	0	1	2	3	4	5
4.- I FEEL FAINT.............................	0	1	2	3	4	5
5.- I HAVE RINGING IN MY EARS................	0	1	2	3	4	5
6.- IT IS HARD TO BREATH.....................	0	1	2	3	4	5
7.- MY BREATHING SEEMS FAST..................	0	1	2	3	4	5

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUIT A BIT	EXTREME
8.- MY BREATH SEEMS IRREGULAR................	0	1	2	3	4	5
9.- I FEEL NAUSEOUS..........................	0	1	2	3	4	5
10.- I FEEL STOMACH PRESSURE.................	0	1	2	3	4	5
11.- I HAVE STOMACH PAIN.....................	0	1	2	3	4	5
12.- MY STOMACH IS UPSET.....................	0	1	2	3	4	5
13.- I HAVE TO URINATE FREQUENTLY............	0	1	2	3	4	5
14.- MY HEARTBEAT SEEMS FAST.................	0	1	2	3	4	5
15.- MY HEART IS POUNDING....................	0	1	2	3	4	5
16.- MY HEARTBEAT SEEMS IRREGULAR............	0	1	2	3	4	5
17.- MY MUSCLES ARE TENSE....................	0	1	2	3	4	5
18.- MY MUSCLES ACHE.........................	0	1	2	3	4	5
19.- I FEEL WEAK.............................	0	1	2	3	4	5
20.- I FEEL CHILLY...........................	0	1	2	3	4	5
21.- I AM SHIVERING..........................	0	1	2	3	4	5
22.- I FEEL WARM.............................		1	2	3	4	5
23.- I FEEL FEVERISH.........................	0	1	2	3	4	5
24.- MY HANDS ARE SWEATY.....................	0	1	2	3	4	5
25.- I AM SWEATING...........................	0	1	2	3	4	5
26.- MY SKIN FEELS SENSITIVE.................	0	1	2	3	4	5
27.- MY EYES FEEL IRRITATED..................	0	1	2	3	4	5
28.- MY EYES ARE WATERY......................	0	1	2	3	4	5
29.- MY VISION IS BLURRY.....................	0	1	2	3	4	5
30.- MY NOSE IS BLOCKED......................	0	1	2	3	4	5
31.- MY NOSE IS RUNNING......................	0	1	2	3	4	5
32.- MY EARS ARE BLOCKED.....................	0	1	2	3	4	5
33.- MY EARS ACHE............................	0	1	2	3	4	5
34.- I CAN'T HEAR WELL.......................	0	1	2	3	4	5
35.- MY MOUTH IS DRY.........................	0	1	2	3	4	5

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUIT A BIT	EXTREME
36.- MY SENSE OF BALANCE IS OFF...............	0	1	2	3	4	5
37.- I FEEL CLUMSY...........................	0	1	2	3	4	5
38.- I FEEL TIRED............................	0	1	2	3	4	5
39.- I FEEL SLEEPY...........................	0	1	2	3	4	5
40.- I HAVE TROUBLE CONCENTRATING............	0	1	2	3	4	5
41.- I FEEL WORRIED ABOUT SOMETHING..........	0	1	2	3	4	5
42.- I FEEL BORED............................	0	1	2	3	4	5
43.- I FEEL IRRITABLE........................	0	1	2	3	4	5
44.- I'M HAPPY...............................	0	1	2	3	4	5
45.- I FEEL WELL.............................	0	1	2	3	4	5
46.- OTHER:________________________________...	0	1	2	3	4	5

THANK YOU FOR YOUR PARTICIPATION.

USE OF A PORTABLE REFREEZABLE HEAD COOLER TO INCREASE HEAT TOLERANCE OF PERSONNEL WORKING IN HOT ENVIRONMENTS AND TO FACILITATE RECOVERY FROM HEAT EXPOSURE

" ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE "

(Phase Two: Post Heat-Exposure with head cooler)

A) LAST 4 DIGITS OF YOUR SSN:_______________.

B) DATE___________________________________.

C) SELECT YOUR TEMPERATURE SENSATION:
( ) COMFORTABLE.
( ) SLIGHTLY WARM.
( ) WARM.
( ) HOT.
( ) VERY HOT.
( ) PAINFULLY HOT.

D) DEFINE YOUR WORK LOAD IN ACCORD WITH THE FOLLOWING WORK INDEX:

( ) EASY WORK.
( ) LIGHT WORK.
( ) MODERATE WORK.
( ) HEAVY WORK.
( ) EXHAUSTING WORK.

E) DO YOU THINK YOU COULD HAVE CONTINUED AND DONE MORE WORK ? ( ) YES.
( ) NO.

F) DID THE HEAD COOLER IMPEDE YOUR WORKING ? HOW ? WHERE (head,neck) ?

( ) YES......HOW:_______________, WHERE:_______________.
( ) NO.

INSTRUCTIONS : Indicate whether you have any of the symptoms below RIGHT AT THIS MOMENT by circling the appropiate number for each item. Answer all items. (Note: It is possible for you to have none of the symptoms below. However, since it is important that you read every statement, respond to each statement individually.)

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUIT A BIT	EXTREME
1.- I HAVE A HEADACHE........................	0	1	2	3	4	5
2.- MY HEAD IS THROBBING.....................	0	1	2	3	4	5
3.- I FEEL LIGHT HEADED......................	0	1	2	3	4	5
4.- I FEEL FAINT.............................	0	1	2	3	4	5
5.- I HAVE RINGING IN MY EARS................	0	1	2	3	4	5
6.- IT IS HARD TO BREATH.....................	0	1	2	3	4	5

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUIT A BIT	EXTREME
7.- MY BREATHING SEEMS FAST	0	1	2	3	4	5
8.- MY BREATH SEEMS IRREGULAR	0	1	2	3	4	5
9.- I FEEL NAUSEOUS	0	1	2	3	4	5
10.- I FEEL STOMACH PRESSURE	0	1	2	3	4	5
11.- I HAVE STOMACH PAIN	0	1	2	3	4	5
12.- MY STOMACH IS UPSET	0	1	2	3	4	5
13.- I HAVE TO URINATE FREQUENTLY	0	1	2	3	4	5
14.- MY HEARTBEAT SEEMS FAST	0	1	2	3	4	5
15.- MY HEART IS POUNDING	0	1	2	3	4	5
16.- MY HEARTBEAT SEEMS IRREGULAR	0	1	2	3	4	5
17.- MY MUSCLES ARE TENSE	0	1	2	3	4	5
18.- MY MUSCLES ACHE	0	1	2	3	4	5
19.- I FEEL WEAK	0	1	2	3	4	5
20.- I FEEL CHILLY	0	1	2	3	4	5
21.- I AM SHIVERING	0	1	2	3	4	5
22.- I FEEL WARM	0	1	2	3	4	5
23.- I FEEL FEVERISH	0	1	2	3	4	5
24.- MY HANDS ARE SWEATY	0	1	2	3	4	5
25.- I AM SWEATING	0	1	2	3	4	5
26.- MY SKIN FEELS SENSITIVE	0	1	2	3	4	5
27.- MY EYES FEEL IRRITATED	0	1	2	3	4	5
28.- MY EYES ARE WATERY	0	1	2	3	4	5
29.- MY VISION IS BLURRY	0	1	2	3	4	5
30.- MY NOSE IS BLOCKED	0	1	2	3	4	5
31.- MY NOSE IS RUNNING	0	1	2	3	4	5
32.- MY EARS ARE BLOCKED	0	1	2	3	4	5
33.- MY EARS ACHE	0	1	2	3	4	5

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUIT A BIT	EXTREME
34.- I CAN'T HEAR WELL........................	0	1	2	3	4	5
35.- MY MOUTH IS DRY..........................	0	1	2	3	4	5
36.- MY SENSE OF BALANCE IS OFF..............	0	1	2	3	4	5
37.- I FEEL CLUMSY............................	0	1	2	3	4	5
38.- I FEEL TIRED.............................	0	1	2	3	4	5
39.- I FEEL SLEEPY............................	0	1	2	3	4	5
40.- I HAVE TROUBLE CONCENTRATING.............	0	1	2	3	4	5
41.- I FEEL WORRIED ABOUT SOMETHING...........	0	1	2	3	4	5
42.- I FEEL BORED.............................	0	1	2	3	4	5
43.- I FEEL IRRITABLE.........................	0	1	2	3	4	5
44.- I'M HAPPY................................	0	1	2	3	4	5
45.- I FEEL WELL..............................	0	1	2	3	4	5
46.- OTHER:________________________________...	0	1	2	3	4	5

THANK YOU FOR YOUR PARTICIPATION.

Section 9

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